CONSTRUCTION SPECIFICATION

NV-99. FLEXIBLE MEMBRANE LINING

(Ethyl Propylene Diene Monomer, Poly Vinyl Chloride, and Polypropylene)

1. SCOPE

The work shall consist of furnishing, transporting, and placing a flexible membrane liner to the elevations, grades and cross sections as shown on the drawings or as staked in the field.

2. MATERIALS

Liners shall have a nominal thickness as specified on the drawings and be specifically manufactured to be suitable for use in exposed and buried conditions. The liner shall conform to the material properties in Table 1, 2, or 3. A manufacturer's certificate shall be furnished showing that the material was manufactured and tested in accordance with the American Society for Testing and Materials (ASTM) methods listed in the Tables.

3. SHIPPING AND STORAGE

The flexible membrane liner shall be shipped to the job site in a manner not to damage the rolls or folded prefabricated panels. The panels and rolls shall be stored on a flat, clean surface. The surface shall be free of sharp protrusions to protect the panels from puncture, dirt, grease, water, moisture, mechanical abrasion, excessive heat, or other damage.

All flexible membrane liners shall be free of damage or defect. Each package delivered to the job site shall be labeled with the membrane type, the manufacturer’s name or symbol, manufacture date, production lot, dimensions, and thickness or weight of the material.

4. SUBGRADE PREPARATION

The area to be lined shall be drained and allowed to dry until the surface is firm. It must support people and equipment that must travel over it during installation of the flexible membrane liner. All cut and fill slopes in the area to be lined shall be constructed in accordance with the drawings (no steeper than 2 horizontal to 1 vertical). Required subgrade fill shall be placed in layers with a maximum thickness of 6 inches prior to compaction. The fill soils shall be disked or worked in such a manner as to obtain a maximum clod size of 4 inches prior to compaction. Each layer shall be compacted by a minimum of one pass over the entire surface of the fill by a fully loaded rubber-tired scraper or a tamping roller. Operation of the compaction equipment will be continuous over the entire area during fill operations. Fill materials shall have a moisture content sufficient to insure the required compaction is achieved. The adequacy of fill moisture content and compaction will be approved by the Technician.

The support soil layer in intimate contact with the flexible membrane shall have a clean, compacted, and regular surface free of abrupt angle changes, stone, and small cavities. This layer should also be able to compensate for the differential settling of the soil and facilitate the installation of a drainage system, if required. The final surface should be

smooth and uniform with no abrupt changes in elevation. Stumps and roots shall be removed. Rocks (larger than 3/8" and all fractured or angular rocks), hard clods, and other such material shall be removed, rolled with a smooth-wheeled vibratory roller, or covered with a compacted cushion of fine soil. The foundation area shall be smooth and free of projections that can damage the flexible membrane.

An anchor trench to provide permanent anchoring for the liner shall be excavated in accordance with the drawings. The anchor trench should be a minimum of three feet back from the top of the slope. Minimum trench dimensions shall be 16 inches deep and 12 inches wide.

5. PLACEMENT

The flexible membrane liner shall be installed by a manufacturer or a supplier-authorized contractor/installer. The installation by the contractor shall comply with manufacturer's recommended procedures and applicable specifications.

The installation contractor shall provide a panel layout drawing, to be approved by the person approving the design or construction prior to fabrication. This plan shall be based on this specification and the construction plans and will indicate the position of the panel field seams. The placement of the panels will proceed according to this plan.

The method chosen to unfold the prefolded panels shall not cause scratches or crimps in the flexible membrane and shall not damage the supporting soil or any underlying geotextile.

The flexible membrane must be kept in place to prevent down slope movement and/or wind uplift. The flexible membrane may be anchored in various ways, at the top of the embankment, at the bottom, or at an intermediate bench. The flexible membrane shall extend on the bottom of the anchor trench over at least 12 inches and up the back of the trench 6 inches.

The liner shall not be deployed during fog, precipitation, high humidity, condensation, in the presence of excessive winds, or when sheet temperatures are less than 32°F or greater than 122°F.

The liner shall be loosely spread over the foundation with sufficient slack (approximately two percent) to accommodate thermal expansion and contraction expected during construction. The panel shall be allowed to relax at least 30 minutes before seaming or attachment to structures.

If panels are joined in the field, each panel shall be laid out and positioned to keep the number and length of the flexible membrane field joints to a minimum and consistent with proper methods of flexible membrane installation. The method used to place the panels shall minimize wrinkles (especially differential wrinkles between adjacent panels).

Seams shall be oriented down, not across the slope. Sharp corners shall be avoided. Panel overlaps shall shingle down slope. Horizontal and T-shaped seams shall not be placed on slopes. No base T-shaped seam shall be closer than 5 feet to the toe of the slope. Seams shall be aligned with the least possible number of wrinkles or "fishmouths".

Adequate loading (e.g. sand bags, rubber tires, or similar items that will not damage the liner) shall be placed to prevent relocation of the compensating wrinkles or uplift by wind. In case of high winds, continuous loading is recommended along edges of panels to minimize risk of wind flow under the panels.

The top edge of the liner shall be placed in the anchor trench and anchored with compacted backfill. Compact the backfill by wheel rolling with light rubber-tired equipment or a manually directed power tamper.

Motorized equipment contact and/or traffic shall not be allowed on the liner. Portable generators may be positioned on the lined area provided that the liner is protected by an adequate cushion of geotextile or an additional layer of liner material.

No equipment or tools shall damage the liner by handling, traffic, or by other means. Personnel working on the liner shall not smoke, wear damaging shoes, or engage in other activities that could damage the liner. Use of metal tools shall be kept to a minimum.

6. SEAMING

a. Double-Wedge Fusion Seam

Field seams shall be made by overlapping adjacent liner panels a minimum of 4 inches and fusion welding the overlapped sheets using double-wedge fusion welders. Seams between panels shall be field welded using the Installer's seaming apparatus and technique.

Prior to fusion seaming, all areas that are to become seam interfaces will be cleansed of dust and dirt. Seam joining shall not take place unless the sheet is dry. Seam joining should not be attempted when the ambient sheet temperature is below 45^{O}F or above 90^{O}F. Seam joining may take place if it can be demonstrated that competent welds can be achieved down to 32^{O}F or up to 125^{O}F sheet temperature.

b. Fillet Extrusion Seams

Extrusion welding shall be used only at areas which cannot be welded by using the double-wedge fusion welder (i.e., repairs, T-seams, etc.). For extrusion welds the liner shall be abraded, preheated and pressed together to align for welding. Minimum overlap of liner panels shall be 3 inches.

c. Ethyl Propylene Diene Monomer (EPDM) Sealing

The seaming of adjacent panels should be performed immediately after the relaxation of the membrane. All panels must be installed without tension and without wrinkles, overlapping by at least 6 inches. All seams on slopes must be parallel to the slope with no horizontal seams allowed.

Two overlapping flexible membrane panels are seamed by means of a patented splicing tape or cap strip system according to the techniques and using the materials recommended by the manufacturer.

d. Poly Vinyl Chloride (PVC) Chemical Fusion Method

Chemically fused seams require the use of either a bodied (thickened) or nonbodied chemical fusion agent. The seams are made by first overlapping the PVC liner material a minimum of 6 inches and then placing a controlled application of chemical fusion agent between the two sheets. Pressure is applied to adhere the sheets and any excess fusion agent that may seep from between the seams is wiped off of the liner. A roller or paddle is used to disperse the fusion agent and eliminate any air bubbles.

e. Additional Seaming Requirements

When several membranes meet at a common point, only three sheets may overlap each other.

When field seaming the materials, clean the area with water and dry it if it is contaminated with mud, etc. prior to completing the seam.

Movement of the flexible membrane during seaming and the first few minutes after seaming is completed will be avoided.

Only the number of panels that can be spliced during the construction day shall be deployed.

7. SEAM TESTING

a. Seam Testing

EPDM
At the start of a shift or the beginning of each day, the seaming crew shall complete a trial seam of approximately 10 feet in length. From the trial seam, 1-inch wide strips will be cut for testing in the field tensiometer (3 in peel and 3 in shear). These tests are carried out in accordance with ASTM D413. Test seams shall meet the requirements shown in Table 1. The same requirements can be expected for specimens taken from a destructive field seam cut out when required.

Polypropylene and PVC
Seam tests shall be conducted under field conditions by the installer at the beginning of each seaming period, once in the morning and once in the afternoon. Three specimens shall be tested by a tensiometer in shear and peel modes. Test seams shall meet the requirements shown in Table 2 or Table 3. Each specimen shall be 1 inch wide with the grip separation rate of 2 inches per minute. All peel tests shall result in Film Tear Bond (FTB) failure.

b. Non-Destructive Testing (NDT)

EPDM

All field seams must be tested non-destructively over 100% of the seam area. The method for NDT of EPDM is the air lance (ASTM D4437). The air lance method uses a jet of exit pressure of 50 psi directed through a 0.2 inch diameter orifice. The jet of air is directed at the upper overlap edge of the seam to detect unbonded areas. When an unbonded area is located, air passes through the area and inflates the overlap.

Polypropylene and PVC

The installer shall non-destructively test all field seams over their full lengths. The installer shall furnish all test equipment.

(1) Air Pressure Tests shall be performed on all double-wedge fusion seams. The air pressure test equipment and procedures shall conform to this specification and the liner manufacturer's specification. Seal both ends of the seam to be tested. Insert the pressure needle into the seam's air channel. Pressurize the air channel through the needle to 25-30 psi. Monitor any pressure loss for 5 minutes. A loss of pressure in excess of allowable pressure loss or a continuous loss of pressure is an indication of a leak. Allowable pressure losses are as follows:

Material Thickness mil	Allowable Pressure Loss, psi
30	5
40	4
50	4
60	3

Terminate the test by relieving the pressure from the opposing end of the seam. The pressure shall immediately drop to zero upon opening the opposing end of the seam. If not, the seam channel shall be checked for obstructions and re-tested. All defects shall be marked for repair.

(2) Vacuum Box Tests shall be performed on all extrusion welds. The vacuum box equipment and procedures shall conform to this specification and the liner manufacturer specification. Apply soapy water solution to the seam area to be tested. The vacuum box, equipped with a transparent viewing window, shall be centered over the seam area and a vacuum of 3-5 psi shall be drawn. The seam area shall be visually monitored for any soap bubbles for 15 seconds. Seam testing shall continue by overlapping a minimum of 3 inches between each test interval. All defects shall be marked for repair.

c. Destructive Testing

If required, seam samples shall be cut at no more than one sample per 500 feet of weld for destructive seam testing. All destructive seam samples shall be tested by a tensiometer in shear and peel modes. Test seams shall meet the requirements shown in Table 1, 2 or 3. Each specimen shall be 1 inch wide with the grip separation rate of 2 inches per minute. (EPDM use 20 in/min) All peel tests shall result in Film Tear Bond (FTB). Repair holes in liner resulting from destructive seam sampling immediately and vacuum test in accordance with procedures described in this specification.

8. APPURTENANCES

a. Gas Vents or Vent Pipes shall be installed in accordance with the drawings to provide adequate venting for the liner system.

b. Pipe Boots for all pipes shall be fabricated in the field from the same liner as shown on the drawings. Pipe boots shall be clamped to the pipe as shown on the drawings to provide a leak-free attachment.

c. Egress Strips shall be installed at the locations shown on the drawings. Egress strips shall consist of plastic link fencing or similar material able to resist long-term exposure to sunlight and freezing. The strips shall be anchored at the top and toe of the slope by weaving a strip of the liner through the fence and welding it to the line. Additional anchoring may be needed if agitation of the structure contents will occur.

9. REPAIRS

All defective liner and seams shall be repaired and non-destructively tested prior to completion of the installation.

a. Tears, Punctures, Material Defects

All tears, punctures, material defects in the liner shall be repaired by installation of a patch over the defective area. Surfaces of the liner, which are to be patched, shall be cleaned and allowed to dry. All patches shall be round or oval, made of the same liner material and extend a minimum of 6 inches beyond the edges of the defect area.

b. Seam Repair

All failed seams shall be repaired by installing a cap strip over the entire length of the failed seam. The cap strip shall be of the same liner material and shall extend beyond the failed seam a minimum of 6 inches in all directions.

10. PLACEMENT OF CONCRETE

Placement of concrete pads and ramps shall be in accordance with the drawings and shall conform to Construction Specification NV-31, Reinforced Concrete. All reinforcement shall be deformed steel bars and shall be placed on flat-footed plastic rebar chairs. Welded wire mesh will not be allowed. All reinforcement steel splices shall be fully tied to avoid loose ends. On slopes, concrete shall have a low slump to prevent sloughing down slope during placement. Concrete shall be formed and placed in a manner that prevents any penetration of the liner. Concrete forms should be sandbagged to hold them in place.

Alternatively, concrete appurtenances may be constructed prior to liner placement with flexible membrane strips cast into the concrete per manufacturers specifications. Bottom strips shall be installed in high stress areas as shown on the drawings.

11. COVER MATERIALS

Membrane liners shall be protected from puncture by the use of cover materials, if required by the manufacturer. Maximum allowable particle size of soil cover material shall be 3/8-in., and rounded in shape, unless the liner is cushioned by a non-woven geotextile. Cover materials must be sufficiently stable to resist sliding on the side slopes because of the weak shear plane created by the membrane. Side slopes shall not be steeper than 3H:1V when a cover material is used. Membranes shall be covered or otherwise protected in areas that will be traversed by livestock, deer, or equipment.

12. FINAL TESTS AND INSPECTION

Upon completion of the work, the installation shall be subjected to a final inspection. All work in the system therein being tested shall be complete, cleaned and ready for use. The work shall meet the requirements as to the line, grade, cleanliness and workmanship. Any discrepancies shall be repaired.

13. BASIS OF ACCEPTANCE

The acceptability of the reinforced concrete shall be determined by inspection to check compliance with all the provisions of this specification, with respect to the drawings, and the minimum installation requirements.

Materials used shall be certified as meeting the requirements of this specification. The installing Contractor shall certify that the installation complies with the requirements of this specification. A written guarantee shall be furnished that protects the Owner against defective workmanship and materials for no less than one year.

TABLE 1
Requirements for EPDM Flexible Membrane Liner

Property	Test Method	45 mil	60 mil
Tolerance on Thickness, %	ASTM D 412	±10	±10
Specific Gravity	ASTM D 297	1.15 ± .05	1.15 ± .05
Tensile Strength, psi	ASTM D 412	1305	1305
Seam Strength	ASTM D 413 (1 in. wide at 20 in./min)		
Shear, lb/in		35	35
Peal, lb/in		14,CBM*	14,CBM*
Elongation, %	ASTM D 412	300	300
Tear Resistance, lb/in	ASTM D 624	150	150
Brittleness Temp	ASTM D 746	-49°F	-49°F
Ozone Resistance	ASTM D 1149	No Cracks	No Cracks
Heat Aging 28 days @ 240°F	ASTM D 573		
Tensile, psi		1205	1205
Elongation, %		200	200
Water Resistance Change in wt, % immersion 7 days @ 150°F	ASTM D 471	+8, -2	+8, -2
Water Vapor Perm, mils	ASTM E 96	2.0	2.0

*Cohesive Bond Mode (CBM)

TABLE 2
Requirements for Polypropylene Flexible Membrane Liner

Property	Test Method	30 mil	40 mil
Gauge (nominal)	----------	30	40
Thickness, mils	ASTM D 751	± 5%	± 5%
Density, g/cc	ASTM D 1505	.91	.91
Tensile Properties	ASTM D 638		
Yield stress, psi		750	900
Break stress, psi		2725	2725
Elongation at break, %		600	650
Elongation at yield, %		47	60
Tear Resistance, lb/in	ASTM D 1004	395	395
Low Temp, Impact, °F	ASTM D 1790	-40 °F	-40 °F
Dimensional Stability, %	ASTM D 1204	.4	.4
Volatile Loss, % loss	ASTM D 1203	.2	.2
Hydrostatic Resistance, psi	ASTM D 751	90	90
Puncture Resistance, lb	ASTM D4833	36	49

TABLE 3
Requirements for PVC Flexible Membrane Liner

Property	Test Method	30 mil	40 mil	50 mil	60 mil
Gauge (nominal)	----------	30	40	40	40
Thickness, mils	ASTM D 1593	± 5%	± 5%	± 5%	± 5%
Specific Gravity	ASTM D 792	1.2	1.2	1.2	1.2
Tensile Properties	ASTM D 638				
Break stress, psi	Method A (MD&TD)	73	97	121	145
Elongation at break, %	Method A (MD&TD)	350	400	425	450
Modulus at 100%	Method A (MD&TD)	34	41	50	60
Tear Resistance, lb/in	ASTM D 1004, Die C	8.5	10.5	13	15
Low Temp, Impact, °F	ASTM D 1790	-29 °C	-29 °C	-29 °C	-29 °C
Dimensional Stability, %	ASTM D 1204 (MD&TD)	3	3	3	3
Volatile Loss, % loss	ASTM D 1203 (A)	.7	.5	.5	.5
Hydrostatic Resistance, psi	ASTM D 751 (A)	100	100	100	100
Peal Strength, lb/in*		15	15	15	15
Shear Strength, lb/in		58.4	77.6	96	116
Water Vapor Transmission, cm/sec	ASTM D 814, max	$5x10^{-9}$	$5x10^{-9}$	$5x10^{-9}$	$5x10^{-9}$

* or FTB (Film Tear Bond): A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area